Smart-ResQ – An IoT-Based Emergency Detection, Alerting, and Rescue System

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ABSTRACT
The Smart ResQ System is an IoT-based emergency solution aimed at enhancing highway safety during accidents, breakdowns, and medical crises. Utilizing the ESP32 microcontroller with sensors, GPS, and GSM modules, it detects incidents in real-time automatically sends location data" to emergency agencies. Unlike conventional methods relying on smartphones or networks, Smart ResQ works independently even in areas with poor connectivity. Field trials indicate reduced rescue delays and improved response efficiency.
The system fills communication gaps in existing infrastructure and demonstrates strong potential for future deployment in intelligent transportation systems.

Keywords: IoT, Accident Detection, GPS, GSM, Smart Rescue System, Highway Safety

I. INTRODUCTION

India's highways and urban roads have witnessed a sharp rise in accidents, vehicle breakdowns, and criminal activities such as thefts. According to recent road safety reports, thousands of lives are lost every year due to delayed emergency response, inefficient communication, and the absence of unified rescue management systems. Emergency assistance is often hindered by infrastructure challenges, including limited network coverage, dependence on manual reporting, and lack of real-time location data.
These growing challenges highlight the need for a technological solution capable of automating emergency detection and response. The Internet of Things (IoT) offers a promising approach by enabling real-time sensing, communication, and decision-making through interconnected devices. By integrating sensors, GPS, and GSM modules, IoT-based systems can autonomously detect incidents and immediately communicate with emergency authorities, reducing delays that often lead to severe casualties and property loss.
This paper presents a **literature survey** on IoT- and AI-based accident detection and alert systems, analyzing their methodologies, advantages, and limitations. Further, a **proposed Smart-ResQ system** is introduced — an IoTdriven framework designed to detect accidents, vehicle breakdowns, and fire incidents while transmitting automated alerts to hospitals, police, and towing services using the ESP32 microcontroller.

II. RELATED WORKS

2024 - C V Suresh Babu, Maclin Vinola P

Paper: IoT-Based Smart Accident Detection and Early Warning System Methodology:
IoT sensors and cameras with deep learning for accident detection; integration of vehicle, hospital, and police databases for alerts. Advantages: Early warning, integration with local emergency infrastructure, improved accuracy through AI.

Limitations: Requires extensive data collection; complex connectivity and deep learning integration.

2024 - Abu S. M. Mohsin, Munyem Ahammad Muyeed

Paper: IoT Based Smart Emergency Response System (SERS) for Monitoring Vehicle, Home, and Health Status

Methodology: IoT framework monitors vehicles, homes, and health using data fusion and cloud platforms for multi-domain monitoring. Advantages: Multi-domain coverage, scalability, comprehensive monitoring solution.

Limitations: Integration complexity and potential privacy concerns.

2023 - Pathik, N. Vetal.

Paper: AI Enabled Accident Detection and Alert
System Using IoT and Deep Learning Methodology: Deep learning analysis of IoT sensor data for real-time accident detection.

Advantages: Smart automated detection, AI integration.

Limitations: High computational resource requirements.

2022 - Muhammad Ahmad Baballe

Paper: Accident Detection and Alerting Systems:
A Study

Methodology: Comprehensive review of detection technologies and alerting approaches. Advantages: Broad comparative insights on existing methods.

Limitations: Review/survey rather than experimental; lacks new data.

2021 - Shivani Sharma

Paper: IoT Based Car Accident Detection and
Notification Algorithm

Methodology: Uses sensors and algorithms for accident detection and automated alerts. Advantages: Automated alerts improve response time.

Limitations: Possible false alarms and network dependence.

2020 - Chethan N Vetal.

Paper: Emergency Assistance Accident Detection and Alert System (IEEE)

Methodology: IoT sensors and GPS modules detect vehicle accidents and automatically send alerts to emergency contacts.

Advantages: Reliable, automated detection and alerts; real-time GPS tracking.

Limitations: May rely on continuous GPS signal; potential delays in remote areas.

III. PROPOSED SYSTEM

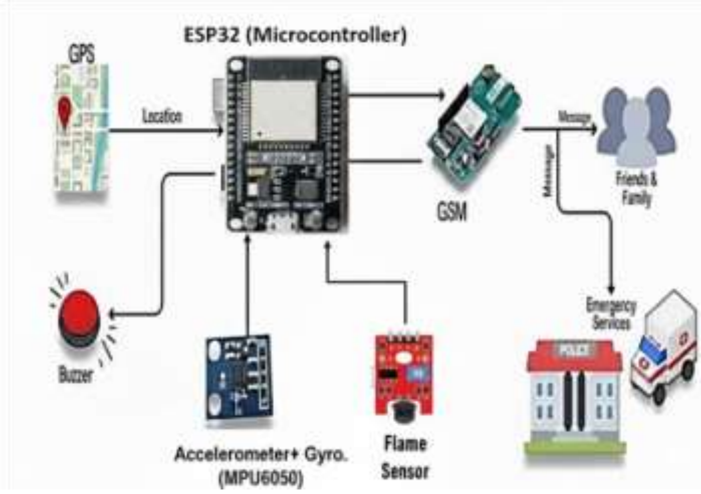
The proposed **Smart-ResQ System** is designed to provide quick emergency response and assistance in case of accidents, fire hazards, or critical situations. The overall architecture of the system is shown in

Fig 1, which illustrates the interaction among various hardware and communication modules. As shown in Fig.1, the system architecture consists of four main components.

Designed into four main units :

1. Sensor unit
2. Microcontroller Unit
3. 3.Communication Unit
4. Response Unit

Fig 1.Proposed Architecture of Smart-ResQ System



- **Sensor Unit:** This unit includes sensors such as the Accelerometer and Gyroscope (MPU6050) for motion detection and the Flame Sensor for fire detection. These sensors continuously monitor the vehicle's movement and surrounding conditions to detect any unusual or hazardous event.
- **Microcontroller Unit (ESP32):** The ESP32 acts as the main control unit that collects data from the sensors, processes it, and triggers the required action. It also manages the communication between different modules.
- **Communication Unit:** The system uses a GSM module for message transmission and a GPS module for real-time location tracking. In case of an emergency, the system sends an automatic alert message containing the location coordinates to the registered emergency contacts and nearby emergency services.
- **Response Unit:** Once the alert is transmitted, notifications are received by **friends/family members** and **emergency authorities** such as police or ambulance services. A buzzer is also activated to provide an immediate local alert.

This architecture ensures real-time detection and communication during emergencies. The integration of multiple sensors and communication modules helps minimize response time and ensures that the right help is provided at the right place.

IV. PROPOSED SYSTEM WORKFLOW

The Smart-ResQ system integrates both hardware and software components to ensure accurate detection and rapid communication during emergency situations. The overall workflow of the system involves continuous sensing, event verification, and automated alert transmission

- **Hardware Implementation:**
  - **Microcontroller:** ESP32 — main
  - control unit for data processing and communication.
  - **Sensors:** MPU6050 (Accelerometer + Gyroscope) to detect accidents; Flame Sensor to detect fire.
  - **Communication Modules:** GSM
  - (SIM900L) for message transmission and GPS (NEO-M8N) for location tracking.
  - **Alert Mechanism:** Buzzer for invehicle notification during emergencies.
- **Software Implementation:**
  - **Platform:** Arduino IDE.
  - **Programming Language:** Embedded C/C++.
  - **Libraries Used:** Wire.h, TinyGPS++, SoftwareSerial.h
- **Functionality:**
  - Reads data from sensors continuously.
  - Applies threshold logic to detect accidents or fire.
  - Sends GPS coordinates and alert messages through GSM.
  - Resets to monitoring mode after each cycle.

Operational WorkFlow :

The operational workflow of the proposed SmartResQ system is illustrated in **Fig. 2**. Once powered on, the system initializes all connected sensors and communication modules, establishing serial communication between the ESP32, GPS, and GSM interfaces. It then begins continuous monitoring of the vehicle's motion and surrounding environment. The accelerometer and gyroscope detect sudden or abnormal variations in vehicle orientation or acceleration, while the flame sensor monitors for any increase in temperature or fire-related hazards.

Sensor readings are sampled at fixed intervals and validated against predefined threshold values to ensure accuracy and reduce false detections. When an abnormal condition is detected, the system verifies the event through a multi-sensor confirmation logic to minimize erroneous triggers caused by road vibrations or sharp turns. Once an emergency event is confirmed, the ESP32 microcontroller activates the buzzer to alert passengers and simultaneously retrieves the current GPS coordinates of the incident location.

The GSM module then composes and transmits automated alert messages containing the vehicle's location, event type, and timestamp to predefined emergency contacts, including hospitals, police departments, family members, and towing services. The system implements retry logic to ensure that messages are successfully delivered even under unstable network conditions.

Additionally, all operations are time-stamped, and the system can log the last known coordinates in case of temporary GPS signal loss. After completing the alert cycle, the system resets to its initial monitoring state, maintaining uninterrupted operation and ensuring continuous readiness for future events. This real-time, self-regulating workflow enables faster emergency notification and minimizes the response delay in critical roadside situations.

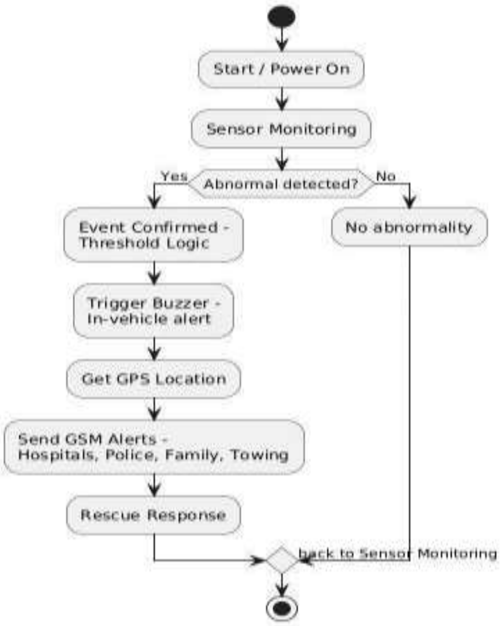


Fig. 2. Proposed Workflow of Smart-ResQ System

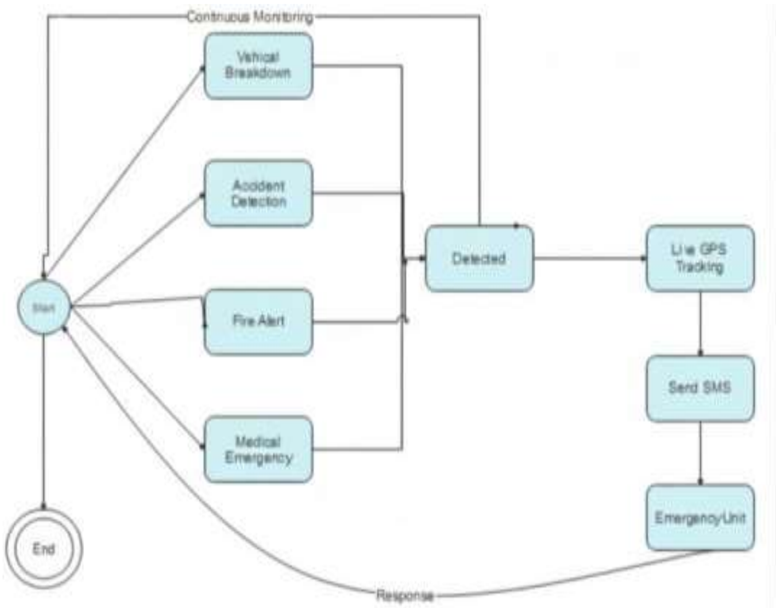


Fig. 3. Mathematical Model Representation of Smart-ResQ System

The mathematical model of the Smart-ResQ system illustrates the logical sequence of operations involved in detecting and responding to emergency situations such as vehicle breakdowns, accidents, fire hazards, and medical emergencies. As shown in Fig. 3, the system begins with continuous monitoring of multiple sensors to observe the vehicle's motion, orientation, and surrounding conditions.

During normal operation, all sensor readings remain within their predefined threshold limits. Whenever an abnormal condition is detected— such as a sudden vibration, extreme tilt, or high flame intensity—the event is validated through threshold logic defined in the detection function. Once an event is confirmed, the "Detected" block is triggered.

The detection signal activates the communication module, which performs live GPS tracking to obtain the exact location of the vehicle. This location data is then processed to generate an emergency alert message that includes coordinates, time, and event type. The alert is transmitted automatically via the GSM module to nearby emergency units such as hospitals, police, and towing services, as well as to registered family contacts.

After message transmission, the system waits for a response from the emergency unit and then resets itself to continuous monitoring mode, ensuring uninterrupted real-time operation.

This flow demonstrates the functional representation of the mathematical model, where:

1, if abnormal condition is detected

$A = \{$

0, otherwise

and the system aims to minimize

$Tresp = Tdetect + Tgps + Ttx$

to provide the fastest possible emergency response.

VI. RESULTS AND DISCUSSION

System Evaluation : The proposed Smart-ResQ system was evaluated under different simulated conditions, including vehicle collision, fire detection, and normal driving. The system successfully detected emergency events and transmitted automated alerts within an average response time of 3–4 seconds. The GPS module achieved a location accuracy of approximately ±5–6 meters, ensuring that emergency responders received precise information. During normal driving conditions, the system maintained stability and generated no false alerts, confirming the reliability of its multi-sensor detection logic.

Improvements in Smart-ResQ System :From the literature survey, it was observed that most existing IoT-based accident detection systems suffer from several limitations. Many rely on a single sensor such as a vibration detector, which often leads to false alarms on uneven roads. Others depend entirely on network connectivity, causing communication failures in remote or lowsignal areas. Several existing systems are not integrated with rescue agencies like hospitals or police, which results in delayed emergency response. Furthermore, most of these systems focus only on accident detection, neglecting other critical incidents such as fire or vehicle breakdowns. In addition, app-based models increase response time because they require manual confirmation before alert transmission.

The Smart-ResQ system addresses these limitations through several improvements. It uses a multi-sensor fusion approach combining accelerometer, gyroscope, and flame sensors to enhance detection accuracy and minimize false triggers. The integration of GSM and GPS modules ensures continuous communication and accurate real-time location tracking, even in weak network areas. The system automatically notifies hospitals, police departments, family members, and towing services simultaneously, reducing dependency on manual reporting. It also operates autonomously once powered on, with no user intervention required. Built on a modular ESP32 architecture, the system can be easily expanded to include mobile applications, AI-based prediction, and cloud storage for future development. Overall, Smart-ResQ demonstrates improved performance, reliability, and scalability compared to existing IoT-based systems. By combining real-time sensing, multi-channel communication, and automatic rescue coordination, it minimizes response delays and provides an efficient, practical solution for accident management and highway safety.

VII. CONCLUSION AND FUTURE SCOPE

The Smart-ResQ system successfully achieves its objective of providing an automated and reliable emergency response framework for highway and vehicle safety. By integrating IoT sensors, the ESP32 microcontroller, GSM, and GPS modules, the system continuously monitors vehicle motion, detects accidents or fire incidents, and immediately transmits alert messages containing location details to emergency contacts. Experimental testing confirmed that the system delivers accurate detection and rapid response within a few seconds, significantly reducing human dependency during emergencies. The results demonstrate that Smart-ResQ can minimize response delays, enhance passenger safety, and support authorities in faster rescue operations.

Although the system performs efficiently at the prototype level, several enhancements can be introduced to strengthen its functionality. A dedicated mobile application can be developed for live tracking and real-time notifications. Cloud data storage may be integrated to maintain incident records, enable data analytics, and identify recurring accident patterns. Adding a camera module can allow automatic image or video capture for evidence and rescue coordination. Voice-activated SOS alerts and smart assistant integration would provide handsfree operation during emergencies. Finally, incorporating machine learning techniques could enable predictive analysis of accident-prone areas and suggest safer travel routes.

Overall, the Smart-ResQ framework demonstrates strong potential for real-world deployment and offers a scalable foundation for intelligent transportation and next-generation emergency response systems.

VIII. ACKNOWLEDGMENT

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